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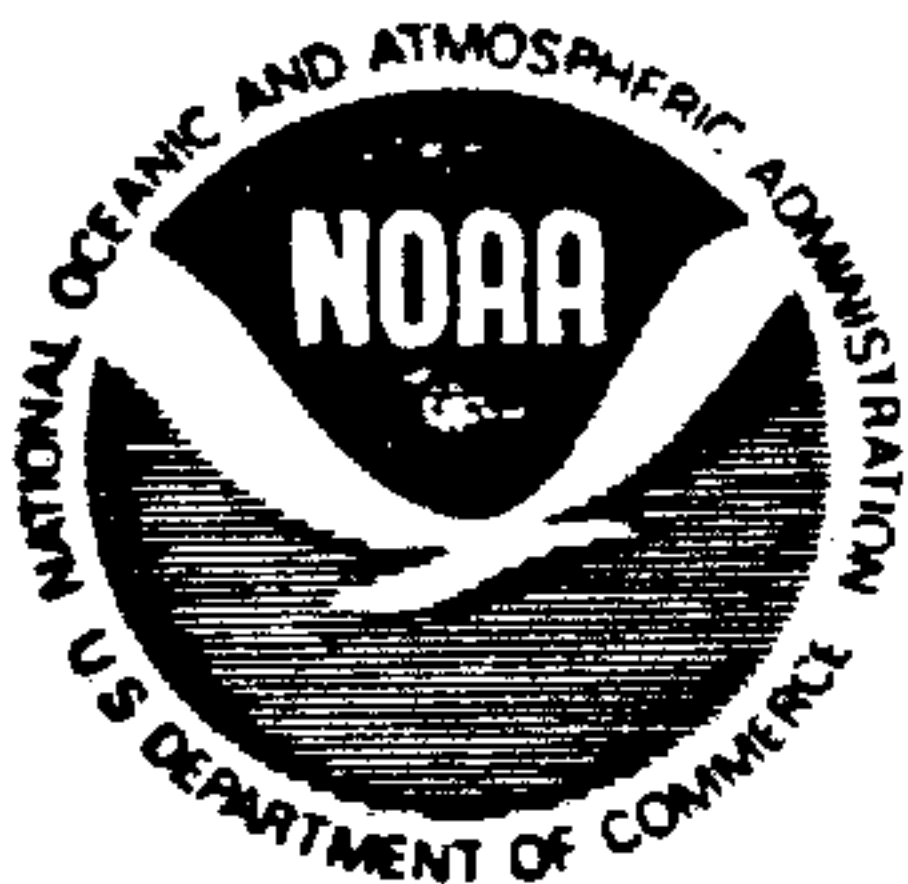
Estimates of Natural and Fishing Mortality
for White Shrimp in the Gulf of Mexico

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# INTRODUCTION

Rates of survival, fishing mortality and natural mortality must be estimated for the commercially important shrimp species in the Gulf of Mexico to have effective management of the fisheries. A mark-recapture study on white shrimp (P. setiferus) carried out in Louisiana in 1977 provides data for white shrimp survival and mortality estimates.

Only one previous mark-recapture study provides estimates of mortality rates for white shrimp in the Gulf of Mexico. Klima (1974) used stained shrimp released in mid-August, 1963, in Galveston Bay, Texas, and recaptured through mid-October. Fishing mortality was estimated at 0.104 to 0.131, natural mortality at 0.041 to 0.121 and total mortality at 0.164 to 0.226 per week; these estimates utilized fishing effort. However, the estimates are reported by the author to be questionable.

The available effort data for the period and location of this study are compiled by month and statistical area. However, most of the recaptures of marked shrimp occur within 4 to 5 weeks of release in a small portion of the statistical area. Thus the effort data cannot be utilized in this study. This paper presents estimates of fishing and natural mortality which are effort-free or based on an assumption of constant fishing effort over a limited period of time.

## Materials and Methods

### 1. Data

The data used in this study are from inshore releases during the mark-recapture experiment carried out in Caillou Lake, Louisiana, in the summer and fall of 1977. Offshore releases were not recaptured in numbers sufficient for good mortality estimates. White shrimp were marked with numbered plastic ribbons and released near where they were first caught. In 1977, inshore waters were closed to shrimping until August 15. Before that date 18277 shrimp were released in Caillou Lake; 18362 were released after August 15. The shrimp were generally 40 to 70 mm tail length at release. The fishing was apparently very intense and continuous in the lake at the beginning of the fishing season, especially on the first two days. By the third week of the season, catches of the groups released prior to the season were very spotty, in contrast to the extremely high catches reported earlier. For some groups, F was zero while for other groups F was positive. Thus only the catches early in the season were used for certain estimates where a homogeneous period was necessary. The release and recapture data, including recaptures for the first 13 days of the season, are summarized below.

## Pre - season releases

| group (i)        | : | 1    | 2    | 3    | 4    | 5    | 6    | 7    | 8    | 9    |
|------------------|---|------|------|------|------|------|------|------|------|------|
| release date     | : | 7/18 | 7/19 | 7/20 | 7/21 | 8/1  | 8/2  | 8/3  | 8/9  | 8/10 |
| $N_i$            | : | 971  | 3487 | 3616 | 1498 | 2103 | 2851 | 847  | 1506 | 1398 |
| $t_i$            | : | 27   | 26   | 25   | 24   | 13   | 12   | 11   | 5    | 4    |
| preseason catch  | : | 8    | 13   | 33   | 12   | 17   | 40   | 10   | 0    | 4    |
| 13 day catch     | : | 75   | 106  | 161  | 65   | 246  | 293  | 142  | 263  | 285  |
| total catch      | : | 110  | 158  | 282  | 109  | 372  | 450  | 209  | 367  | 390  |

## During season releases

| group (i)    | : | 1    | 2   | 3    | 4   | 5    | 6    | 7    | 8   | 9   | 10   | 11  | 12   | 13   | 14   | 15   |
|--------------|---|------|-----|------|-----|------|------|------|-----|-----|------|-----|------|------|------|------|
| release date | : | 9/12 | 9/13| 9/14 | 9/19| 9/20 | 9/21 | 9/22 | 9/27| 9/28| 10/11| 10/13| 10/17| 10/18| 10/19| 10/20|
| $N_i$        | : | 1892 | 137 | 1642 | 483 | 1487 | 1413 | 1227 | 540 | 627 | 1274 | 754 | 2098 | 2068 | 1410 | 1310 |
| total catch  | : | 205  | 26  | 120  | 37  | 84   | 153  | 134  | 74  | 69  | 133  | 81  | 100  | 84   | 72   | 41   |

$N_i$ is the number released, the "13 day catch" is the catch during the first 13 days of the fishing season for the pre-season releases, and $t_i$ is the number of days between the release and the beginning of the season for the pre-season releases.

## 2. Estimators of survival and mortality

### a) Ricker's two-release method

When two releases are made before a sample is taken, then the probability of survival between the releases can be estimated by maximum likelihood (Ricker 1975, p. 123; Seber 1973, p. 222.) In this case, the sample consists of returns of tagged shrimp by commercial and recreational fishermen during some portion of the season. Thus there are 3 time periods, beginning with the first release ($t_1$), the second release ($t_2$) and the sampling period ($t_3$).

Then

$$\hat{S}_1 = \frac{C_{13}}{N_1} \bigg/ \frac{C_{23}}{N_2} \qquad (1)$$

where

$S_1$ = the probability of survival in the 1st time period,

$C_{ij}$ = the catch of the ith release group during the jth time period,

and

$N_i$ = the number of fish released in the ith release group.

It must be assumed that all marked fish from both releases which are alive at time $t_2$ have the same probability of surviving to the sample and of being caught. Thus the instantaneous rates of fishing mortality (F and M) must be the same for both release groups. However, M and F need not be constant through the sampling time. If the daily total mortality rate between the releases ($Z_1$) is constant, then

$$S_1 = e^{-Z_1(\Delta t_1)}$$

so that

$$\hat{Z}_1 = -\ln(\hat{S}_1)/\Delta t_1$$

where $\Delta t_1$ is the number of days in time period 1. For pairs of pre-season releases, $F_1$ is negligible, thus an estimate of the daily instantaneous mortality rate between the releases is

$$\hat{M}_1 = -\ln(\hat{S}_1)/\Delta t_1 \qquad (2)$$

b) **Maximum likelihood, survival rate constant**

When the average values of M and F do not vary from one time period to the next (i.e., when M and F are "constant"), then $\hat{S}$ can be obtained by maximum likelihood from Paulik's expression for the joint distribution of the numbers of recaptures (Seber 1973, p. 287.) This method can be applied with any number of release groups (released before or during the season) which are all considered as one in the samples.

Let

$C_{.j}$ = number of tagged fish caught in the jth sampling period ($j = 1,2,\ldots,J$) where the sampling periods are 1 time unit long,

$C_{..}$ = number of tagged fish caught in all sampling periods $(\sum_j C_{.j})$,

and $\qquad x_. = \sum_j (j-1)\, C_{.j}$

Then the estimate of the survival rate is the solution to

$$\left(\sum_{j=0}^{j-1} j\hat{S}^j\right) \Big/ \left(\sum_{j=0}^{j-1} \hat{S}^j\right) = x_./C_{..} \qquad (3)$$

$\hat{S}$ can be obtained through iterative procedures or with a table provided in the reference (for $J \leq 9$).

When several releases are made before the fishing season, then the maximum likelihood estimate of M can also be obtained by solving simultaneously the equations

$$\sum_{i=1}^{I} \frac{k_i(C_{i.} - N_i \hat{A}_i)}{1 - \hat{A}_i} = 0 \qquad (4a)$$

$$\sum_{i=1}^{I} \frac{(C_{i.} - N_i \hat{A}_i)}{1 - \hat{A}_i} = 0 \qquad (4b)$$

where     I = the number of release groups

$$\hat{A}_i = \hat{\beta} \hat{\phi}^{k_i} \qquad (5)$$

$$\phi = e^{-\hat{M}} \qquad (6)$$

$k_i$ = number of time units between the ith release and the beginning of the fishing season,

and     $\beta$ = the probability of a tagged fish surviving initial tagging mortality, being recaptured and being reported during the sampling.

When I = 2 and $k_2$ = 0, equations (4a) and (4b) are a special case of Ricker's two-release method.

The parameter $\gamma = \nu\rho$ can also be estimated,

·where     $\nu$ = the proportion of each release group which survives any initial tagging mortality

and     $\rho$ = the probability that a recaptured tag is reported.

When $\nu$ and $\rho$ are constant, then $\gamma$ is the proportion of $N_i$ actually utilized in the estimates, or the "effective proportion" of $N_i$ (Seber 1973, p. 280.) When $S$ and $F$ are constant (as in equation (3)

then
$$\hat{\gamma} = \hat{\beta}/\hat{u}_J \qquad (7)$$

where $\hat{u}_J = F (1 - e^{-Zt})/Z$ is the rate of exploitation and $t$ is the length of the sampling period.

If $S$ is not constant over the sampling period, $\gamma$ can be approximated by using

$$\hat{u}_J = \hat{F}_J (1 - e^{-\hat{Z}_J})/\hat{Z}_J \qquad (8)$$

in equation (7), where $\hat{F}_J$ and $\hat{Z}_J$ are mortality rates calculated for the whole sampling period (considered as one time unit.)

c) Regression estimates, survival rate constant

When $M$ and $F$ are assumed to be constant and a release is made during the season, then $Z$, $F$ and $M$ can be estimated from Paulik's regression model:

$$Y_j = \log (N/C_j) = -(\hat{Z} + \log \hat{u}_1) + \hat{Z}j \quad (j = 1,\ldots,J) \quad (9)$$

where $\hat{u}_1 = \hat{F} (1 - e^{-\hat{Z}})/\hat{Z}$,

$C_j$ = number of tagged shrimp caught in the jth time period after release ($j = 1,\ldots,J$)

and $N$ = number of shrimp released.

Thus the slope of the line is $\hat{Z}$, the intercept is $a = -(\hat{Z} + \log \hat{u}_1)$ and

$$\hat{F} = \hat{Z} \, e^{-a}/(e^{-\hat{Z}} - 1). \qquad (10)$$

An estimate of Z can also be made from several release groups
when all groups are considered as one and sampling is started
at any time after all the releases have been made. Thus

$$Y_j = \log (N/C._j) = a + \hat{Z}j \qquad (11)$$

Where $C._j$ is the catch over all groups in the jth time interval
after sampling begins. However, the estimate of $\hat{F}$ in equation
(10) will not be valid. (This will be discussed in the next
section.)

3. Assumptions

All the above estimators require that immigration and emigration
are negligible and that tags are not lost from the shrimp. If a loss
other than natural or fishing death (such as permanent emigration)
occurs in the tagged population, it will be included in the estimate
$\hat{M}$ (i.e., natural mortality will be overestimated.)

Initial tagging mortality and nonreporting of recaptured tags
have the effect of decreasing the number of tagged released ($N_i$) and
can seriously affect the mortality estimates. If $\nu$ and $\rho$ (section 2b)
are constant, then using $N_i$ instead of $\gamma N_i$ where $\gamma = \nu\rho$ will not
affect Ricker's $\hat{M}$ since the same $\gamma$ will cancel in the numerator and
denominator of $\hat{S}_1$. Similarly, using $N_i$ instead of $\gamma N_i$ in the
regression model does not affect $\hat{Z}$ but does cause overestimation of M
and underestimation of F (Paulik 1963; Seber 1973 p. 280.) The
maximum likelihood estimate of S is not affected by the release number.

When the regression model is applied to several release groups considered as one and sampling begins simultaneously, the true N (number of tagged shrimp alive at the beginning of the sampling period) is not known. However, as with the uncertainty induced by $\nu$ and $\rho$ above, this will not affect the estimate of Z but only the intercept of the model. Natural and fishing mortality can be estimated from this revised model if the number of tagged shrimp alive just before the sampling begins can be estimated.

DISCUSSION AND RESULTS

1. Pre-season releases, Ricker's method

a)    Estimates were made for $M_1$ using the catches ($C_{i3}$) from several
different time periods, varying from 1 day to 20 weeks.  Each possible
pair of release groups was used for a separate estimate.  Also, the
groups released on adjacent days were combined into 3 sets (released
7/18 - 21, 8/1 - 3, 8/9 - 10), using the average release date and sum
of the $N_i$ for each set.

The estimates of M vary greatly (from 0 to about .12 per day) with
the choice of pairs of release groups, but not with the choice of time
period for the catch.  The estimates made with the 3 combined sets are
quite stable.  Using the catch of the first 13 days of the season the
estimates are:

| Sets | $M_1$ (per day) |
| --- | --- |
| I   vs II | 0.0770 |
| I   vs III | 0.0713 |
| II  vs III | 0.0616 |

with $\overline{\hat{M}_1}$ = .0700 per day.

Assuming that M is constant for several weeks after the start of
the fishing season, these estimates of $M_1$ seem too high.  The population
size of marked fish (N) and the fishing mortality rates (F) calculated
from the daily catches and the $N_i$ (by using the catch equation) support

this. These calculations of N and F through time may be inaccurate since initial tagging mortality and nonreporting of tags are not known. However, if M is constant at .07 per day from the time of the first release, the tagged populations would all be extinct in fewer than 60 days from release (before the end of September.) Yet about 8% of the reported recaptures were after that time.

The estimate of M will be high if

(1) other losses" are included in $\hat{M}_1$

(2) fishing mortality is higher for the second release than the first release.

Both of these events can happen if the tagged shrimp move to an area where F is less than in the release area.

Most of the recaptured shrimp from these release groups were recaught within Caillou Lake. Let area 2 be defined as the waters outside of Caillou Lake (roughly, west of $91^\circ 50'$ W and east of $90^\circ 50'$ W longitude and south of $29^\circ 10'$ N latitude.) The total marked catch for various time periods and the percent of the total caught in area 2 is tabulated below.

CATCH OF MARKED SHRIMP

| Set | Release Groups | Release Dates | Recap Dates: 8/15-8/19 | | 8/20-8/24 | | 8/25-8/29 | | 8/15-8/27 | | 8/15-12/31 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Total | Area2 | Total | Area2 | Total | Area2 | Total | Area2 | Total | Area2 |
| I | 1-4 | 7/18-21 | 245 | 14.7% | 110 | 26.4% | 62 | 43.5% | 407 | 21.4% | 561 | 33.2% |
| II | 5-7 | 8/1-3 | 432 | 11.8% | 178 | 13.5% | 76 | 19.7% | 681 | 13.2% | 929 | 23.8% |
| III | 8-9 | 8/9-10 | 355 | 4.8% | 136 | 6.6% | 61 | 18.0% | 548 | 6.6% | 729 | 17.8% |

Two trends can be seen in the catches:

(1) As the fishing season progresses, the percent caught in Area 2 increases for each release set;

(2) In each time period, the percent caught in Area 2 is greater for the earlier releases than for the later releases.

Both trends and the high estimate of M indicate that the shrimp are continuously leaving the lake. By the start of the season, a larger proportion of the earlier releases than the later releases will have emigrated from the lake. The rate of fishing mortality in the lake at the very start of the season is probably higher than the rate in outside waters. Thus the later releases will be subject to more fishing deaths than the earlier releases at the opening of the season (when most of these tagged shrimp were caught.)

b) Under the assumption that the estimates of M are affected by emigration from Caillou Lake, I recalculated the estimates using only the portion of the catch taken in the lake. Thus the instantaneous total mortality rate would be

$$Z_C = F_C + X_C$$

where $F_C$ and $X_C$ are the instantaneous rates of fishing and "other" mortality, respectively in Caillou Lake only. The estimate of $X_C$ now includes the instantaneous rates of natural mortality ($M_C$) and of emigration from the lake ($E_C$).

The estimates using 13 days of catch for the three release sets are:

| Sets | $\hat{X}_C$ |
|---|---|
| I vs II | 0.0845 |
| II vs III | 0.0712 |
| I vs III | 0.0796 |

The mean of these estimates is $\overline{\hat{X}}_C = 0.0784$.

2. Maximum likelihood estimates, preseason releases

a) Natural mortality

The catch in Caillou Lake of tagged shrimp from all preseason releases in the first 13 days of fishing was used in the maximum likelihood estimate for M (equations (4a.) As before, this actually estimates $X_C$ where $X_C$ includes natural and "other" losses from Caillou Lake. The data are summarized below:

| Group (i) | $N_i$ | $k_i$ | $C_{13}$ |
|---|---|---|---|
| 1 | 971 | 27 | 59 |
| 2 | 3487 | 26 | 85 |
| 3 | 3616 | 25 | 130 |
| 4 | 1498 | 24 | 46 |
| 5 | 2103 | 13 | 203 |
| 6 | 2851 | 12 | 260 |
| 7 | 847 | 11 | 128 |
| 8 | 1506 | 5 | 246 |
| 9 | 1398 | 4 | 266 |

The estimate is $\hat{X}_C = 0.079$ per day, which is similar to the estimates obtained with Ricker's Model.

The parameter $\beta$(equation (5)) is also estimated from (4a) and (4b), giving $\beta = .2588$ (to be used later.)

b). Survival and fishing mortality

Using the three sets of release groups, $\hat{S}$ was calculated with the daily catches in Caillou Lake (equation (3).)

Daily survival rates are apparently nonconstant at the beginning of the season. Assuming constant $X_C$ the fishing mortality rate on the first 2 days of the season is twice as high as on following days; the rate declines after day 10 of the season.

Grouping the catches by 2 days for days 3 to 10 of the season yields the estimates

$$\hat{Z}_C = .1147$$

and
$$\hat{F}_C = \hat{Z}_C - \hat{X}_C = 0.0357 \text{ per day,}$$

where $\hat{X}_C = .079$ is the maximum likelihood estimate of all losses other than fishing. The regression estimate for $Z_C$ is .1145, agreeing with the maximum likelihood estimate.

c) The "effective proportion" of the release

The effective proportion of the release, $\gamma$, is estimated by equation (7) using $\beta$ and $u_J$. Since survival is not constant for the sampling period (days 1-13 of the fishing season), the estimate of $P_J$ is not straightforward but can be obtained as follows.

For any given period, let $N_o$ and $N'$ be the number of tagged shrimp alive at the beginning and the end of the period, and F,Z and C be the mortality rates and catch for the period. Then

$$N' = N_o e^{-Z}$$

$$C = N_o F(1-e^{-Z})/Z$$

and

$$N_o = CZ/F(1-e^{-Z}).$$

Using these relations and the values C = 633 for days 1 to 2, C = 657 for days 3 to 10, Z = .1147 and F = .0357 per day for days 3 to 10 (from the previous section), the number of shrimp alive at the beginning of day 1 is estimated to be 4800. The total catch for the 13 day sampling period is C = 1423. Thus

$$1423 = 4800 \, \hat{u}_J,$$

$$\hat{u}_J = 0.2965,$$

and

$$\hat{\gamma} = \hat{\beta}/\hat{u}_J = 0.8728.$$

This estimate for $\gamma$ can then be used to adjust the release numbers $(N_i)$ for tagging mortality and nonreporting in other estimates using the release numbers.

## 3. Mortality estimates for releases during the fishing season

Fifteen groups were released between September and November. The groups released on adjacent days were combined into release sets for the estimates since recaptures from individual groups were low and erratic. The recaptures of these later release groups show definite weekly cycles with recaptures generally peaking on Wednesday

and Thursday of each week. Thus catches were combined to estimate weekly mortality rates.

The recaptures of these later releases are not so predominantly inshore as are recaptures of the preseason releases. Thus I considered all shrimp to be subject to the same fishing mortality regardless of recapture location.

Weekly catches for each set were calculated beginning on Saturday of each week. The data are summarized by release set:

| Week Beginning On | Set:<br>Number Released:<br>Release Dates: | I<br>3671<br>9/12-14 | II<br>4610<br>9/19-22 | I+II<br>8281<br>9/12-22 | III<br>1167<br>9/27-28 | IV<br>2028<br>10/11,13 | V<br>6886<br>10/17-20 | IV+V<br>8884<br>10/11-20 |
|---|---|---|---|---|---|---|---|---|
| 9/17 | | 103 | | | | | | |
| 9/24 | | 59 | 93 | 152 | | | | |
| 10/1 | | 19 | 79 | 98 | 24 | | | |
| 10/8 | | 32 | 62 | 94 | 24 | | | |
| 10/15 | | 34 | 47 | 81 | 22 | 48 | | |
| 10/22 | | 14 | 36 | 50 | 16 | 35 | 79 | 114 |
| 10/29 | | | | | 9 | 14 | 39 | 53 |
| 11/5 | | | | | | 7 | 24 | 31 |
| 11/12 | | | | | | 10 | 24 | 34 |
| 11/19 | | | | | | 1 | 7 | 8 |

For all sets, the catches after the fifth or sixth week at large were negligible.

Regression estimates (equation (10)) and maximum likelihood estimates (equation (3)) for weekly Z were obtained for the sets where Z appeared to

be constant. Plots of $Y_j = \log(N/C_{.j})$ versus $j$ for sets I + II show a linear relationship for several weeks of catch, indicating a constant weekly Z. The regression estimate is $\hat{Z} = 0.2413$ per week ($\hat{Z} = 0.0345$ per day) with $R^2 = 0.9103$. The maximum likelihood estimate, $\hat{Z} = .2357$ per week, is in close agreement. The estimates of Z obtained from set II alone are almost identical to those using sets I and II; for set I alone the catches are low and the plot of $\log(N/C_{.j})$ is not linear.

The value of N used in calculating the $Y_j$ is higher than the number of marked shrimp actually alive on 9/24 when the "sampling" began. The estimate of Z is valid, but the regression must be recalculated with a "corrected" N in order to estimate F and M. Assume that the average daily Z calculated above holds for the days between release and the beginning of the first sampling week. Let

$$\hat{N}_i' = \hat{\gamma} N_i e^{-\hat{Z}k_i}$$

where    $N_i$ = the number of tagged shrimp released in group i

        $\hat{\gamma}$ = .8728 is the "effective portion" of the marked population (section 2(c))

        $k_i$ = the number of days between the release of group i and the beginning of the first sampling period (the week beginning 9/24)

and    $\hat{Z}$ = 0.0345 per day from above.

The sum of $\hat{N}_i'$ over the 7 release groups in sets I and II is 5991. The estimates from the resulting regression are

$$\hat{F} = 0.0039$$

and    $\hat{M} = \hat{Z} - \hat{F} = 0.0306$ per day.

These estimates of F and M use the assumption that $\gamma$ from the preseason releases applies to these release groups as well. But increasing or decreasing $\hat{N}_i'$ by 10% still gives $\hat{M}$ of approximately .03 per day.

The other sets do not give the same results as set I + II. For set III, the slope of the relation between $Y_j = \log (N/C._j)$ and j is monotone increasing, indicating a low but increasing Z. Since catches are low, this suggests an increase in natural mortality. However, low release and recapture numbers for this set could make these results unreliable.

For set IV + V, the relation between $Y_j$ and j is somewhat erratic but has a linear trend. The resulting regression yields $\hat{Z} = 0.5757$ per week (0.0822 per day), over twice the mortality rate of set I + II, and $\hat{F} = 0.02$ per week (0.003 per day using the technique of correcting N as for set I + II). Thus $\hat{M} = \hat{Z} - \hat{F}$ is approximately 0.08 per day. The maximum likelihood estimate of Z is .0766 per day, confirming the regression results. However, the lack of stability of the $Y_j$ versus j relationship makes these results somewhat questionable.

It should be noted that the data used in the last regression are for shrimp at large in October and November . In 1977, the Caillou Lake water temperature dropped sharply in early October from a steady high temperature during the summer (Phares 1978). Thus these later release groups were subjected to a very different environment than the release groups in September and earlier. The change in Z suggested by the last regression could indicate a seasonal change in natural mortality or increase in "other losses", such as emigration from the fishery.

# SUMMARY AND CONCLUSIONS

1) The various estimates of average weekly instantaneous mortality

rates are:

| Release Dates | Recaptured Through | Fishing Mortality (F) | Natural Mortality (M) or "other losses" (X)* | Total Mortality (Z) |
|---|---|---|---|---|
| **Preseason** | | | | |
| 7/18-8/10 | 8/27 | | 0.490 | |
| 7/18-8/10* | 8/27* | 0.250* | 0.553* | 0.803* |
| **During Season** | | | | |
| 9/12-9/22 | 10/28 | 0.027 | 0.214 | 0.241 |
| 10/11-10/20 | 11/25 | 0.020 | 0.556 | 0.576 |

*For shrimp remaining in Caillou Lake

2) July-August releases

   a) For shrimp recaptured in all locations, M is very high. The assumption
   of equal fishing mortality for all releases is apparently violated. This
   may be due to emigration of the earlier releases from Caillou Lake.

   b) Assuming equal F in Caillou Lake for all releases, the estimate of average
   "other loss" rate (X) from shrimp recaptured in the lake only includes
   natural mortality and emigration. Fishing and total mortality rates in
   the lake are high in the first 2 weeks of the fishing season.

3) September-October releases

Average weekly mortality rates are assumed constant for 4 to 5 weeks after release.

a)  The estimate of M for September releases is much lower than $\hat{M}$ or $\hat{X}$ for preseason releases.  This estimate is probably not influenced by unequal fishing mortality and emigration as the earlier estimates may be.  Fishing mortality is about a tenth of the rate at the beginning of the season (August.)

b)  The estimate of fishing mortality is slightly lower for October releases than for September releases.  The estimate of natural mortality is again high, indicating a possible increase in natural mortality or other losses from the fishery (such as emigration) due to the changing season.

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